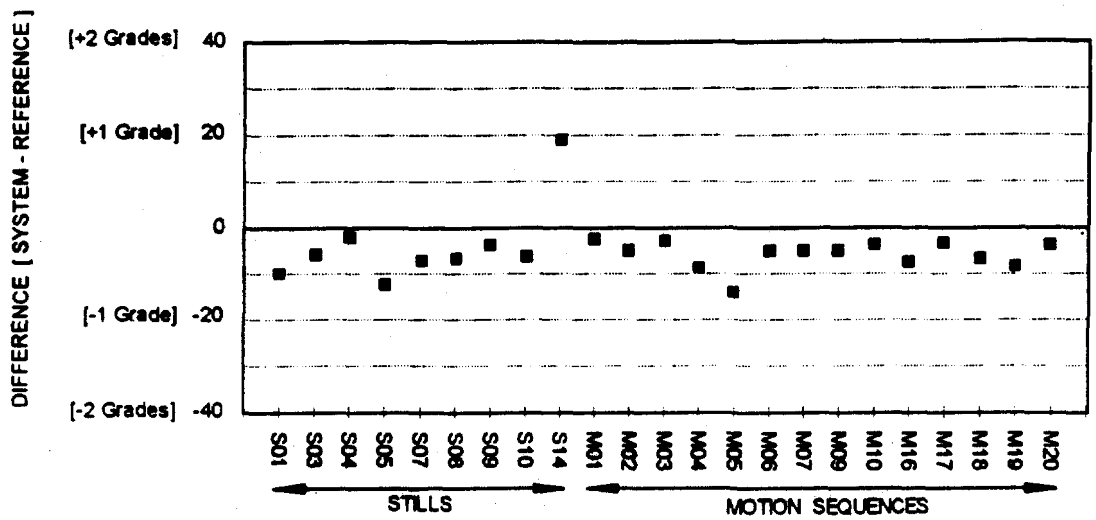

Figure 12-9. Average differences between quality judgments for the 1125-line studio quality reference and for AD-HDTV.

In general, scene cuts were rendered very well, including deliberate test sequences designed to stress the 9-frame MPEG-1 group-of-picture data structure used in AD-HDTV. When viewed in real time, some expert observers saw very slight noise immediately following some of the cuts. When observing still frames, AD-HDTV introduced only slight, localized artifacts and they were gone after a few frames.

When tested for video-coder overload, the image broke up severely into blockiness. When viewed as still frames one of the images persisted for 7 frames. When tested for motion-compensation overload at velocities of 0.4 picture height per second and greater, the system introduced quantization noise and blockiness. At a velocity of 0.8 picture height per second (a speed slow enough for eye tracking), the image was severely impaired by a "dirty window" of blocky noise. No artifacts were noted in response to a sudden stop in movement.

Slight system artifacts became visible when material was subjected to two encode/decode passes through the system. After the second pass, added noise did not cause pictures to be degraded substantially. The appearance of a momentary black panel at the top, after a scene cut from gray, was consistent and quite disagreeable.

The AD-HDTV system exhibited good chrominance dynamic range in red, green, and blue channels.

In examining video quality for gradual degradation, using sequences with very simple images to highly complex ones, expert observers saw very few images other than stills that could be rendered in "usable" form by HP data alone. The observers believed that, for most reasonably active images, the form of gradual degradation embodied in this system produced recognizable pictures having utility only for short, temporary, and infrequent signal fading.

12.4.1.2 Audio Quality

During system-specific tests, expert observers noted that the audio remained useful, but not unimpaired, over the range between the SP and HP noise impairment thresholds. There was no evidence that the audio system failed before the accompanying video.[7]

Objective tests for dynamic range, total harmonic distortion (THD), THD + noise (THD+N), intermodulation distortion (IMD), dynamic intermodulation distortion (DIM), frequency response, and overload versus frequency were not performed.

For co-channel interference of ATV-into-NTSC, at both moderate and weak signal levels, there was no degradation in THD + N over the range of interference tested. For upper adjacent-channel interference of ATV-into-NTSC, at moderate signal level, two receivers showed that BTSC audio began to degrade when the video quality was "unimpaired" while a third receiver showed that audio began to degrade when video quality was between "perceptible, but not annoying" and "slightly annoying." In the test of co-channel ATV-into-NTSC, AD-HDTV caused no significant degradation of NTSC VBI data.

12.4.2 Transmission Robustness

In most regards, AD-HDTV performed as predicted by the proponent. Its performance equalled or exceeded that of NTSC in almost all impairment conditions. Typically the system exhibited immunity to a variety of transmission impairments over a wide range of impairment levels. Beyond that range, the system exhibited a sharp degradation in performance when exposed to all impairments. At even higher levels of noise impairments, the system produced recognizable pictures and usable, but not unimpaired, audio over an additional range. This characteristic has utility only for short, temporary, and infrequent signal fading. In general, all transmission impairments had similar manifestations in the observed video, which were quite different than the effect they produce on NTSC. Transmission impairments and interference, when strong enough, produced display errors and caused jerkiness and randomly spaced rectangular patches of images either to freeze or to display erroneous information for a short duration.

AD-HDTV interference into NTSC had the characteristic of white noise, and produced a graceful degradation. Cable transmission had no adverse effect on AD-HDTV performance.

12.4.2.1 Noise Performance

When AD-HDTV was subjected to random channel noise (based on a 6 MHz noise bandwidth), the carrier-to-noise ratio[8] (C/N) at the TOV was measured and is shown in Figure 12-1. This was the noise threshold level for the SP data. The system had a sharp degradation: the range between the TOV and the Point of Unusability (POU) was 0.75 dB.

Expert observers concluded that the form of gradual degradation embodied in this system has utility only for short, temporary, and infrequent channel fading. The system continued to produce recognizable pictures and usable, but not unimpaired, audio with HP data alone over a range extending about 5 dB beyond TOV.

12.4.2.2 Static Multipath

The system performed well at levels which would be highly objectionable in NTSC. The TOV for echoes of +0.08 μsec, +0.32 μsec and +2.56 μsec were at D/U ratios of 2.1 dB (i.e., echo amplitude of 79%), 0.1 dB (98%), and 4.9 dB (57%), respectively. For an echo of -0.08 μsec, no impairment was observed up to the D/U limit of 0 dB.

12.4.2.3 Flutter

12.4.2.6 Cable Transmission

The subjective tests show that cable transmission *per se* has no adverse effect on AD-HDTV performance.

Among the cable-specific tests conducted, the system performed better than NTSC when subjected to hum (TOV @ 11%); composite triple beat, or CTB, (TOV @ -16 dBc); and composite second order, or CSO, (TOV @ -26 dBc). Its performance was poorer than NTSC when subjected to phase noise (TOV @ -84 dBc), residual FM (TOV @ -0.6 kHz), and local oscillator instability (TOV @ +0.45 kHz, -0.55 kHz).

The threshold values for the ancillary data channel were consistent with the values found in other tests for Gaussian noise, CTB, and hum modulation, and 1 dB worse for phase noise.

12.4.2.7 Co-Channel Interference into ATV

AD-HDTV was much more robust than NTSC to co-channel interference from either NTSC or ATV.

Results are summarized in Figure 12-1. The system performance exhibited a sharp degradation when ATV co-channel interference was increased beyond TOV. The range from TOV to POA was less than 1.6 dB for NTSC-into-ATV co-channel interference, and about 1 dB for ATV-into-ATV co-channel interference.

In subjective tests, NTSC-into-ATV impairment ratings varied from "perceptible, but not annoying" to "very annoying" over a range of 2.6 dB.

12.4.2.8 Co-Channel Interference into NTSC

For co-channel interference into NTSC, impairment ratings varied gradually from "imperceptible" to "very annoying" over a range of 27 dB at weak desired signal level. (See Figure 12-10.) The D/U for a mean impairment rating of 3 is about 34 dB. The interference appeared as random noise in the NTSC picture.

12.4.2.9 Adjacent-Channel Interference

The D/U ratio at the TOV for adjacent-channel interference into ATV is given in Figure 12-1. The D/U ratio for a mean impairment rating of 3 for adjacent-channel interference into NTSC is given also in Figure 12-1. Note that the more negative the D/U ratio, the better the performance. In practice, it is expected that the AD-HDTV signal would be transmitted with an average power at least 10 dB lower than NTSC peak power. Under this assumption, the data indicate that AD-HDTV supports collocation.

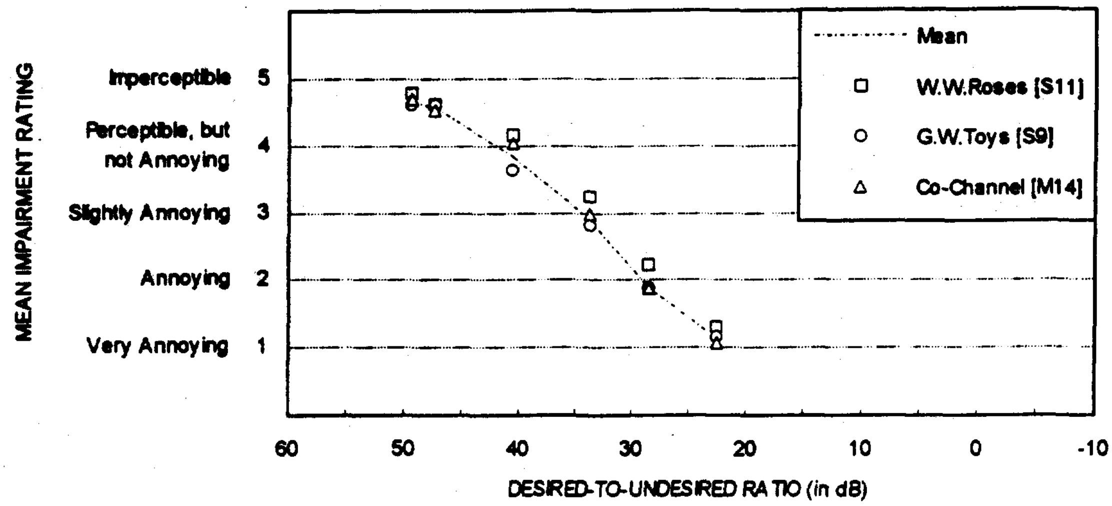

Figure 12-10. Impairment to NTSC when subjected to AD-HDTV co-channel interference for weak signal condition (-55 dBm).

The system exhibited a sharp degradation when subjected to adjacent-channel interference from NTSC and ATV. The range from TOV to POU was about 1 dB.

ATV-into-NTSC impairment ratings varied from "imperceptible" to "very annoying" over a range of about 16 dB. Mean impairment ratings varied from "perceptible, but not annoying" to "annoying" over a range of 5 dB for the upper adjacent-channel and 9 dB for the lower adjacent-channel.

12.4.2.10 Taboo Interference

The taboo performance of AD-HDTV, based on TOV is given in Figure 12-11. Note that the more negative the D/U ratio, the better the performance.

In practice, it is expected that the AD-HDTV signal would be transmitted with an average power at least 10 dB lower than NTSC peak power. Under this assumption, the data show that AD-HDTV can support collocation on the basis of taboo channel interference requirements.

12.4.2.11 Channel Acquisition

Under a variety of channel conditions, the AD-HDTV system fully acquired the signal and displayed a recognizable picture within 2.5 to 5.8 seconds. Due to AD-HDTV hardware

CHANNEL	ATV-into-NTSC		NTSC-into-ATV		ATV-into-ATV	
	Strong	Weak	Strong	Weak	Strong	Weak
n+2	< +1*	-25	-32	-51	-30	-50
n-2	< 0*	-23	-32	-51	-29	-49
n+4	< -2*	-23	<-33*	<-58*	<-33*	-63
n+7	< -2*	-32	<-33*	<-58*	<-33*	<-63*
n-7	< -1*	-31	<-33*	<-58*	<-31*	<-61*
n+8	< 0*	-37	<-33*	<-58*	<-33*	<-63*
n-8	< -1*	-28	<-33*	<-58*	<-32*	<-62*
n+14	< +1*	-25	**	**	**	**
n+15	< -1*	-15	<-30*	<-58*	<-29*	<-59*

* Determination of TOV level was beyond the limits of ATTC's RF test bed range. Consequently, the system has a better performance than the indicated result.

** Test not performed.

Figure 12-11. Taboo threshold of visibility for AD-HDTV (D/U in dB).

implementation limitations, channel change testing was modified by interrupting the carrier; therefore, the measured times do not include tuner synthesizer frequency changes.

12.4.2.12 Failure and Recovery Appearance

In general, all transmission impairments had similar manifestations in the observed video. When transmission path impairments were strong enough to be visible in the observed picture, they caused blockiness and jerky motion. The visible blocks tended to cluster around moving areas, but there were often other, more scattered, blocks of impairments. There was occasional spatial displacement of blocks of the image. When impairments were strong enough that images were constructed solely from HP data, i.e., beyond POU, the general nature of the impairments remained the same — they became worse and led to significant image freezing and occasional complete loss of large areas of the image.

In all cases the picture disturbances had well defined straight boundaries, and in most cases matched the shapes and sizes of system blocks (e.g. 8x8, 16x16, or 16x208 pixels); and did not change appearance while present. System recovery from picture disturbances was rapid (much less than one second).

12.4.2.13 Peak-to-Average Power Ratio

The peak-to-average power ratio was less than 6 dB 99% of the time, and less than 6.7 dB 99.9% of the time.

12.4.2.14 Multiple Impairments

The performance of AD-HDTV, when simultaneously subjected to multiple impairments, is shown in Figure 12-12 for two cases:

(1) The POA for NTSC co-channel interference versus random noise, and

(2) The TOV for composite triple beat versus random noise.

Asymptotes are shown reflecting the measured single impairment performance. The operating region lies above and to the right of the respective curves.

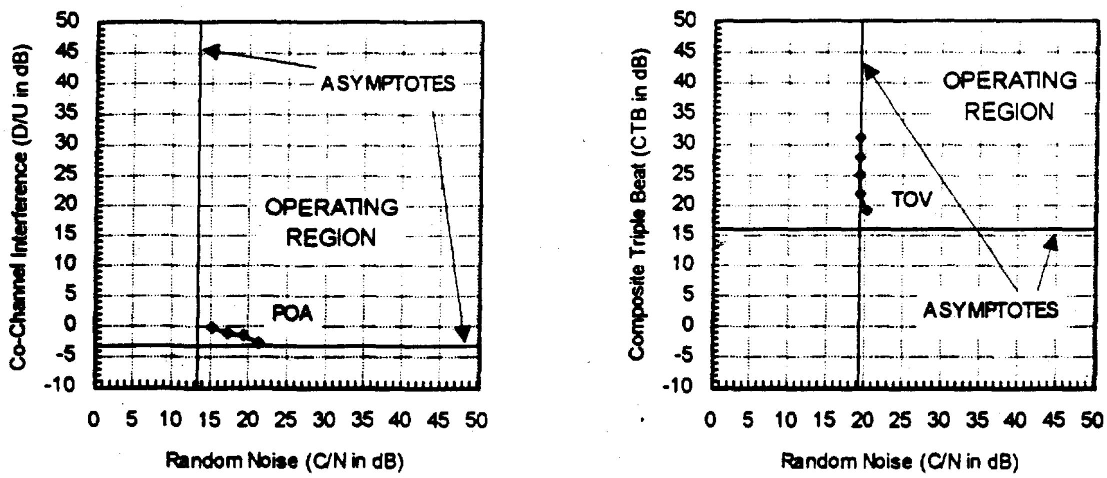

Figure 12-12. Multiple impairments into AD-HDTV. (Left) POA for NTSC co-channel interference and random noise. (Right) TOV for composite triple beat and random noise.

12.4.3 Scope of Services and Features

12.4.3.1 Data

Because of AD-HDTV's asynchronous data multiplexing, there is no hard partitioning of ancillary data. Unassigned service types provide for the delivery of many types of ancillary data. For example, AD-HDTV has provision for carrying text and graphics overlay data that can be sent as a separate service type and superimposed on the display at the receiver. For testing, an allocation of 256 kbits/sec was made for ancillary data, and those data were set aside as SP data. A standard communications interface port for these ancillary data was provided.

12.4.3.2 Encryption

The tested system did not include encryption. The proponent claims that the packet structure has been designed to accommodate encryption and expects to detail the encryption method with industry participation.

12.4.3.3 Addressing

The system provides opportunities for flexible high-data-rate burst-mode delivery of ancillary data. As a limit, the entire channel capacity, 18.5 Mbits/sec, could be dedicated to addressing receivers with decryption keys. Conditional access data can be treated as a special service type and packaged into its own transport cells, or included within the video and audio data.

12.4.3.4 VCR Capability

Although hardware development of VCRs has been reported, hardware has yet to be demonstrated. AD-HDTV has periodically occurring frames that are entirely spatially coded. This is said to provide the ability to reconstruct pictures in fast-forward and reverse scanning modes from digital storage media. Splices and inserts could be made on GOP boundaries. Limited picture cropping can be handled in compressed form if it aligns with macroblock boundaries.

12.4.4 Extensibility

12.4.4.1 To No Visible Artifacts

The proponent points out that AD-HDTV at 17.7 Mbits/sec is already an extension of the baseline MPEG-1 parameters which encode low-resolution video at 1.5 Mbits/sec and believes that it can be extended to virtually any data rate.

12.4.4.2 To Studio Quality Data Rate

AD-HDTV was designed with the anticipation of several levels of related compression. The proponent suggests that a studio standard could be set at 216 Mbits/sec (the data rate of existing studio D-1 recorders) using the same MPEG-1 syntax as AD-HDTV.

12.4.4.3 To Higher Resolution

The proponent claims that AD-HDTV potentially supports the delivery of other video and image formats over appropriate bandwidth channels to special receivers with increased memory. The MPEG-1 core allows resolution up to 4095 x 4095. The proponent has discussed the possibility of introducing ultra-high-definition television by sending augmentation data packets assigned to a unique service type that will be disregarded by older receivers but processed by new receivers.

12.4.4.4 Provision for Future Compression Enhancement

The proponent suggests improved calculation of motion vectors and improvements in bit allocation and prioritization as likely means for picture quality improvement without changing receivers or the data rate.

12.4.5 Interoperability Considerations

12.4.5.1 With Cable Television

Information on the performance of AD-HDTV over cable can be found in Section 12.4.2.6.

12.4.5.2 With Digital Technology

Since this system is all-digital, the advantages of all-digital systems apply.

12.4.5.3 Headers/Descriptors

The AD-HDTV system includes headers and descriptors as defined in the MPEG-1 syntax. In addition, after synchronization, the data link layer identifies the service type. Within the adaptation level, the adaptation header contains information governing the packing of variable-length code words for video, and information used in recovery after channel changes or errors. The video service level includes the actual encoded video information.

All data sent by the AD-HDTV system are grouped into fixed-length cells that contain data of a single particular type. The cells are 148 bytes long including synchronization, service

12.4.5.5 With Film

The proponent claims that AD-HDTV will support an "electronic film" format that eliminates the redundant field to achieve more efficient coding and thus higher quality. Because film has a lower temporal rate, AD-HDTV scans progressively at 24 frames per second with the same format used with video sources. However, in film productions where computer graphics are used extensively, square pixels may be more desirable in the image representation. The proponent claims that AD-HDTV will also provide a progressively scanned 1440 x 810 square pixel format to accommodate film. Most receivers will perform 3:2 pull-down to convert to their 59.94 Hz field rate, but higher-cost receivers could use 3:1 frame repeat to display at 72 Hz.

12.4.5.6 With Computers

Encoding and transmission in AD-HDTV are done in progressive form with a frame rate of 29.97 Hz, favoring interoperability with computers, although testing of this system has been done with interlaced sources and displays requiring format conversions. Pixels are 18.5% wider than high. The proponent has suggested that the system will eventually use progressive sources and displays, and that square pixels can be provided by reduction of the number of active lines to 810.

12.4.5.7 With Satellites

For satellite operation, the proponent has suggested removing the 0.9-rate trellis code used with SS-QAM, reducing the net data rate 21.6 Mbits/sec. The proponent does not anticipate the need for any additional error correction for satellite transmission, although convolutional coding is normally used. The proponent stated that three AD-HDTV programs may be carried in a transponder. However, it is unlikely that more than two will be carried in a typical 36-MHz transponder. The proponent also stated that it is possible to carry AD-HDTV and NTSC signals on the same transponder.

12.4.5.8 With Packet Networks

The data link packet format is based on a "cell relay" asynchronous time-division multiplexing concept similar to the asynchronous transfer mode (ATM) standard that was designed for the broadband integrated services digital network (B-ISDN). The packet header contains information such as priority indicator, service ID and cell sequence number. This provides service-independent transport services such as priority support, service multiplexing, and cell-error detection and correction. For the received bit stream, the transport decoder performs Reed-Solomon decoding and a cyclic redundancy check (CRC) for error detection. Cells received in error after correction are discarded by the demultiplexer. Packet headers include pointers to slices (208H x 16V), so that packet loss results in loss of, at most, a few slices prior to error concealment.

12.4.5.9 With Interactive Systems

According to the proponent, the encoder requires 4 frames of latency. An additional frame is needed for interlaced-to-progressive conversion. Similar delays are present at the receiver and the total latency is 333 msec. The proponent claims that for interactive applications where latency is a concern, an encoder can provide an MPEG-1 bit stream using only forward motion compensation to reduce the coding part of the latency. Acquisition time is reported in Section 12.4.2.11.

12.4.5.10 Format Conversion

12.4.5.10.1 With 1125/60

Up-converting to the Common Image Format (1920 x 1080) requires 8:9 vertical interpolation and 3:4 horizontal interpolation.[9] SMPTE 240M uses 1035 active lines and would require 14:15 vertical interpolation. Colorimetry used by AD-HDTV is intended to be consistent with SMPTE 240M.

12.4.5.10.2 With 1250/50

This difficult conversion is not simplified by the fact that both the source system and the target system are interlaced 2:1.

12.4.5.10.3 With MPEG[10]

AD-HDTV's use of MPEG-1 video and audio compression provides the possibility of interoperability with MPEG computer multimedia applications directly in the compressed bit stream format. The underlying video compression algorithm adheres to the MPEG-1 standard in that parameters allowable within the MPEG-1 definition are used although they are not the MPEG-1 default parameters. Prior to entering the prioritization and transport processors, the compressed video conforms to the MPEG-1 specification. An MPEG-1 bit stream can be obtained from the output of the compression encoder at the interface to the priority processor. Because the tested system used an internal fixed-length representation for MPEG-1 code words at the interface between its compression and prioritization stages, a standard MPEG-1 bit stream was not available as an output. In general, commercially available MPEG-1 decoders are not fast enough to decode the AD-HDTV signal.

---

[9] The 3:4 ratio is based on 1440 pixels per line as proposed by the proponent. The system tested used 1500 pixels per line.

[10] See Section 8.3.8 for a discussion of MPEG, the MPEG-1 standard, and the MPEG-2 development effort.

12.4.5.10.4 With Still Image

AD-HDTV's compression, based on the DCT, is generally compatible with JPEG. The CD-I format is directly compatible with AD-HDTV because CD-I uses the MPEG-1 compression syntax. Photo CD decoding would be possible with straightforward spatial filtering after decompression.

12.4.5.11 Scalability

The picture produced by AD-HDTV's HP signal alone is a substantially reduced-quality image. The decoded artifacts observed in an HP-only reconstruction will depend on the exact priority processing algorithm. Typical priority processor operation results in lower spatial and temporal resolution. The proponent claims that for low cost picture-in-picture and picture-out-of-picture, only the HP signal needs to be processed.

For multiple programs in a single channel, AD-HDTV's prioritized data transport layer provides for asynchronous delivery of multiple service types. Multiple video streams can be assigned individual service types.

12.5 SYSTEM IMPROVEMENTS

12.5.1 Already Implemented

12.5.1.1 Receiver Carrier Recovery Pull-In Range

The purpose of this improvement was to increase the frequency pull-in range of the receiver. The first-order carrier recovery circuit has been upgraded to second-order carrier recovery.

12.5.1.2 Improved Data Prioritization

The purpose of this improvement was to correct difficulties that were noticed during testing.

Occasional difficulties were experienced with the motion compensation hardware which did not perform with full accuracy in the left third of the picture. The motion compensation hardware has been repaired.

The "squelching" circuit that manages the transition between full use of both HP and SP data and the use of only HP data during severely impaired transmission conditions was not working optimally. This circuit has been modified to improve the picture quality that is obtained around the threshold of the SP carrier.

The tested system selected high spatial resolution (but low temporal resolution) codewords for transmission of the HP carrier, a relatively simple approach. Improvements to the prioritization approach have been developed.

12.5.1.3 Tuner Adjustments

To improve upper adjacent-channel rejection, internal tuner adjustments have been made.

12.5.1.4 Receiver Adaptive Equalizer Range

The range of the adaptive equalizer has been increased from ± 4 μsec to ± 8 μsec.

12.5.2 Implemented in Time for Field Testing

12.5.2.1 Trellis Coding

The trellis coding will be modified in order to improve random noise performance, ATV-into-ATV co-channel performance, and performance in the presence of other noise, interference and impairments. Since full implementation of trellis coding hardware was not complete in time for ATTC testing, the tested system used a simpler set partition code. The hardware will be modified to provide the trellis code described in the certification document.

12.5.2.2 Tuner SAW Filter

The purpose of this improvement is to improve both lower and upper adjacent-channel rejection. A new SAW filter will be designed for the tuner.

12.5.2.3 Adjustment of HP/SP Power Ratio

The purpose of this improvement is to allow the HP/SP power ratio to be increased or decreased at a given broadcast station based on the precise terrain and the co-channel and interference environment involved. The ratio will be made variable; two separate automatic gain control (AGC) circuits will be provided in the receiver.

12.5.2.4 Receiver Adaptive Equalizer Range

The range of the adaptive equalizer will be increased further to ± 16 μsec.

12.5.2.5 QAM for Cable

The purpose of this improvement is to allow the choice of transmitting QAM or SS-QAM over cable. For broadcast-originated programming, the SS-QAM signal may be transmitted directly over cable. As an alternative, or for satellite-based distribution of programming, the signal can be remodulated as a QAM signal. The AD-HDTV receiver will be modified to receive either signal form.

12.5.2.6 Multi-Channel Audio

The purpose of this improvement is to comply with the ATSC T3/186 recommendations for multi-channel audio. The ISO-MPEG audio committee is in the process of defining a five channel composite coding extension to MUSICAM, the audio system currently used by AD-HDTV. The MPEG five channel audio system will be incorporated into AD-HDTV. In the event this hardware is not available at the time of field testing, AD-HDTV will incorporate an alternate multi-channel audio system.

[This page intentionally left blank.]

13. CHANNEL COMPATIBLE DIGICIPHER

13.1 SYSTEM OVERVIEW

CCDC, proposed by the American Television Alliance (Massachusetts Institute of Technology and General Instrument Corporation) is a digital simulcast system that requires a single 6 MHz television transmission channel. The video source is an analog RGB signal with alternate 787/788 lines, progressively scanned, a 59.94 Hz frame rate, and an aspect ratio of 16:9. A matrix converts the RGB color signals to YUV signals. The display format is 720 lines by 1280 pixels per line. The video sampling frequency is 75.52 MHz. Chrominance signals are decimated by a factor of two both horizontally and vertically, resulting in a sampling density of one fourth that of the luminance signal. Eight-bit precision is employed for all luminance and chrominance samples. The video compression uses an adaptive form of motion-compensated predictive coding in which prediction differences are spatially transformed using a Discrete Cosine Transform (DCT). A selected subset of the resultant transform coefficients is entropy coded to represent the image that will be reconstructed at the receiver. Information related to the compressed video is entropy coded for transmission, including motion vectors and parameters related to decisions on intra-frame and inter-frame coding. The video encoder uses four processors, each working on one-fourth of the image (full height and one-fourth width panels), with intraframe refresh moving continuously from right to left. Two transmission modes are supported: 32 QAM, the primary transmission mode, and 16 QAM, both with a symbol rate of 5.29 M-symbols per second. The 32 QAM primary mode has a video data rate of 18.88 Mbits/sec and a total transmission rate of 26.43 Mbits/sec. Concatenated trellis coding, Reed-Solomon block coding, and adaptive equalization are used to protect against channel errors. The CCDC system provided six independent digital audio channels using the MIT Audio Coder system for compression. The audio is sampled at 48 kHz. The compressed audio rate is 252 kbits/sec per pair of channels. In addition, a combined auxiliary and control data capacity of 252 kbits/sec is provided

13.2 SPECTRUM UTILIZATION

The CCDC analysis was conducted under two allotment scenarios (using both VHF and UHF channels for ATV stations, and using only UHF channels) and two sets of interference constraints (considering only co-channel interference, and both co-channel and adjacent-channel interference). In addition, the impact of taboos was assessed by re-calculating coverage and interference for each case assuming the taboo performance measured in the laboratory.

Figure 13-1 shows planning factors, specific to the CCDC system, as derived from test results. The numbers in the figure are desired-to-undesired ratios (D/U) in dB. The values for interference into NTSC are based on CCIR Impairment Grade 3 (slightly annoying) as determined from the ATEL subjective tests. Because the ATV service is intended to be an improvement over NTSC, interference into ATV is based on CCIR Impairment Grade 4 (perceptible but not annoying) if the range between the threshold of visibility (TOV) and the point of acquisition (POA) exceeds 5 dB. Otherwise, the TOV power level is used. CCDC demonstrated a "cliff effect" and thus D/U values are based on TOV data. Also, the data show that CCDC can support collocation on both the upper and lower adjacent-channels.

Co-Channel	D/U (dB)
ATV-into-NTSC	+36
NTSC-into-ATV	+8.1
ATV-into-ATV	+16.6

Carrier-to-Noise	+15.4

Adjacent-Channel	D/U (dB)
Lower ATV-into-NTSC	-17.8
Upper ATV-into-NTSC	-17.0
Lower NTSC-into-ATV	-37
Upper NTSC-into-ATV	-37
Lower ATV-into-ATV	-32
Upper ATV-into-ATV	-32

Figure 13-1. Planning factors specific to CCDC.

13.2.1 Accommodation Percentage

CCDC could provide a 100% accommodation of all NTSC assignments for co-channel only, and co-channel and adjacent-channel constraints, under both the VHF/UHF and UHF scenarios. The accommodation is achieved at the expense of reducing the ATV and NTSC service areas. No attempt was made to reduce interference to NTSC service by adjusting either ATV or NTSC power.

13.2.2 Service Area

Figure 13-2 depicts the interference-limited service area of each ATV station, during the transition period, relative to the interference-limited service area of its companion NTSC station under the VHF/UHF scenario, taking into account both co-channel and adjacent-channel constraints. In this graph, the 1,657 current NTSC stations are placed in order of decreasing ATV to NTSC service area ratio. Examination of the graph reveals that 10.9% (180) of the ATV stations under this scenario would have an ATV service area at least 20% larger than their companion NTSC service area and 98% (1,616) would have an ATV service area at least 80% of their companion NTSC service area. The total ATV interference-limited service area for all 1,657 stations is 39.9 million square kilometers.

Figure 13-3 shows the interference statistics for the VHF/UHF scenario. During the transition period, 54.1% of ATV stations would receive no interference. This would rise to 72.3% after the transition period ends. Also during the transition period, 1.8% of the ATV stations would receive interference in more than 35% of their noise-limited coverage area. This would fall to 0.8% after the transition period ends. The total interference area created within the ATV noise-limited coverage area during the transition period is 2.32 million square kilometers. This would decrease to 1.11 million square kilometers after the transition period ends. Of the existing NTSC stations, 59.4% would not receive any new interference because of the ATV service, while 2.3% would receive new interference in more than 35% of their Grade B area. The total new interference into NTSC created under this plan is 1.54 million square kilometers.

When taboos are included in the interference calculations for the VHF/UHF scenario, the number of ATV stations with no interference during the transition period is 51.2%; the number of ATV stations with interference in more than 35% of their noise-limited coverage

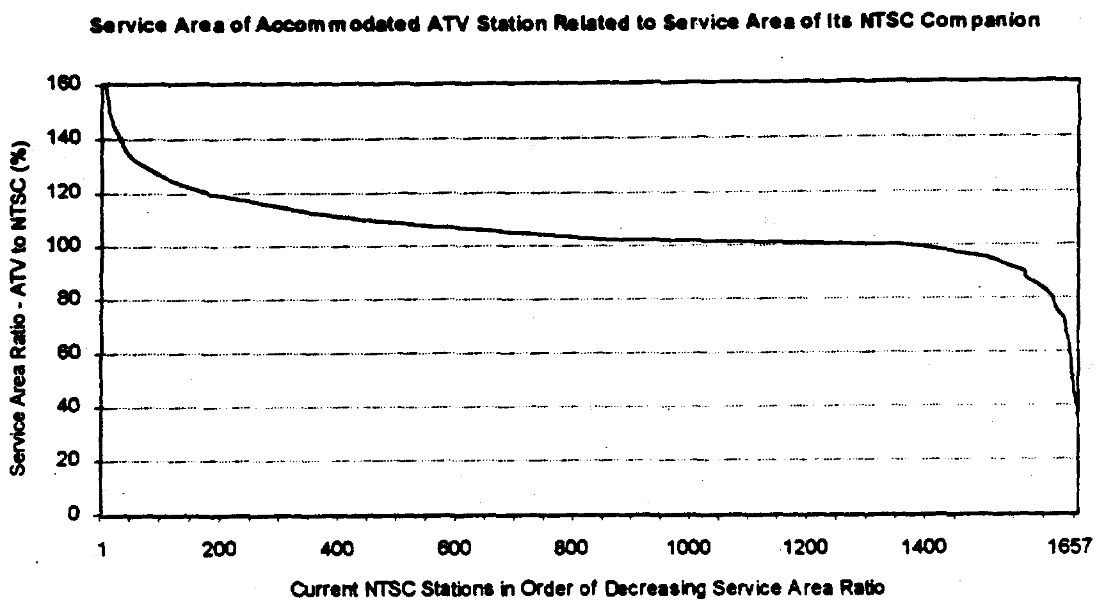

Figure 13-2. CCDC VHF/UHF Scenario — Interference-limited service area of each ATV station relative to the interference-limited service area of its companion NTSC station (co-channel and adjacent-channel constraints).

Interference Area Compared to Coverage Area	ATV Stations with Interference		NTSC Stations with Added Interference Due to ATV
	During Transition	After Transition	
No Interference	54.1 %	72.3 %	59.4 %
0 - 5 %	19.6 %	16.0 %	15.7 %
5 - 10 %	11.3 %	6.0 %	8.0 %
10 - 15 %	5.3 %	2.2 %	5.6 %
15 - 20 %	3.7 %	1.3 %	3.5 %
20 - 25 %	2.0 %	0.5 %	2.8 %
25 - 30 %	1.2 %	0.4 %	1.5 %
30 - 35 %	1.0 %	0.4 %	1.2 %
> 35 %	1.8 %	0.8 %	2.3 %

Figure 13-3. CCDC VHF/UHF Scenario — Interference characteristics (co-channel and adjacent-channel constraints).

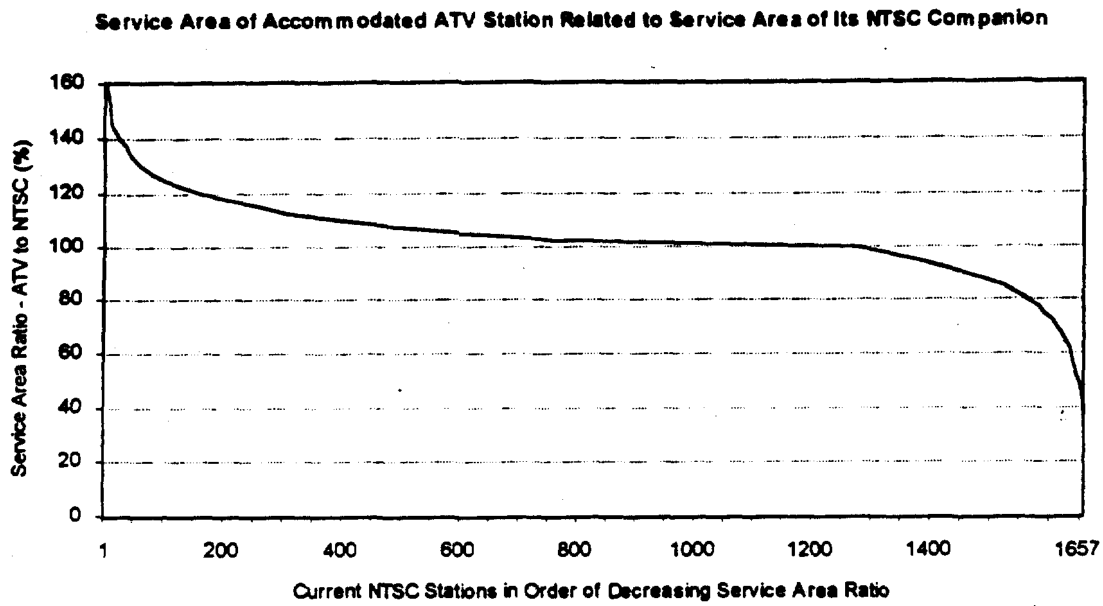

Figure 13-4. CCDC UHF Scenario — Interference-limited service area of each ATV station relative to the interference-limited service area of its companion NTSC station (co-channel and adjacent-channel constraints).

Interference Area Compared to Coverage Area	ATV Stations with Interference		NTSC Stations with Added Interference Due to ATV
	During Transition	After Transition	
No Interference	51.3 %	66.1 %	62.3 %
0 - 5 %	13.5 %	14.5 %	8.8 %
5 - 10 %	10.3 %	7.2 %	5.4 %
10 - 15 %	7.7 %	4.3 %	4.5 %
15 - 20 %	5.9 %	2.5 %	2.9 %
20 - 25 %	3.8 %	1.0 %	2.5 %
25 - 30 %	2.5 %	1.4 %	2.8 %
30 - 35 %	2.1 %	0.8 %	2.1 %
> 35 %	3.0 %	2.1 %	8.7 %

Figure 13-5. CCDC UHF Scenario — Interference characteristics (co-channel and adjacent-channel constraints).

When taboos are included in the interference calculations for the UHF scenario, the number of ATV stations with no interference during the transition period is 48.9%; the number of ATV stations with interference in more than 35% of their noise-limited coverage area is 3.2%. The number of NTSC stations receiving no new interference is 58.7%; the number of NTSC stations with interference in more than 35% of their Grade B area is 8.7%.

When the adjacent-channel constraints of Figure 13-1 are not included in the UHF scenario, the allotment/assignment table is different. In that case, 12.3% (203) of the ATV stations would have an ATV service area at least 20% larger than their companion NTSC service area and 95% (1,579) would have an ATV service area at least 80% of their companion NTSC service area. During the transition period, 57.5% of ATV stations would receive no interference. This would rise to 74.7% after the transition period ends. Also during the transition period, 2.8% of the ATV stations would receive interference in more than 35% of their noise-limited coverage area. This would fall to 2.0% after the transition period ends. Of the existing NTSC stations, 64.1% would not receive any new interference because of the ATV service, while 8.3% would receive new interference in more than 35% of their Grade B area.

The frequency distribution of ATV station average effective radiated power levels needed to

Average Effective Radiated Power Level		Number of TV Stations			
		VHF/UHF Scenario			UHF Scenario
(dBk)	(kW)	Low VHF	High VHF	UHF	UHF
Less than 5	Less than 3.2	12	26	106	106
5 - 10	3.2 - 10.0	5	6	46	47
10 - 15	10.0 - 31.6		11	132	141
15 - 20	31.6 - 100		4	269	277
20 - 25	100 - 316			291	306
25 - 30	316 - 1,000			221	233
30 - 35	1,000 - 3,160			378	390
35 - 40	3,160 - 10,000			150	157
> 40	> 10,000				
TOTAL		17	47	1,593	1,657

Figure 13-6. CCDC power level distribution.

Subsystem	Cost (thousands)
Satellite Receiver, Demodulator, Decoder	$ 13.5
Character Generator, Still Store, Two 28" Monitors	200.0
Routing Switcher (10 x 10), Master Control	125.0
2 ATV VTRs and Monitors	170.0
NTSC Upconverter, including Line Tripler	24.0
ATV-to-NTSC Downconverter	20.0
34" Monitor, Seven 17" Monitors, Eight Decoders	119.0
ATV Encoder	220.0
STL Subsystem	92.5
ATV Modulator, ATV Exciter	30.0
ATV Transmission Subsystem	725.5
TOTAL COST	$1,739.5

Figure 13-7. Equipment cost for a CCDC transitional station.

Using a 2.5 multiplier, the resulting estimated retail price for a CCDC receiver is $2,543 for a 34" direct view receiver and $3,863 for a 56" projector receiver.

Subsystem	34" Widescreen Direct View Receiver	56" Widescreen CRT Type Projector
Signal Processing Components	$ 124	$ 124
Audio Amplifiers and Speakers	30	30
Scan System, Power Supply, and Video Amps	73	201
Display	700	1,050
Cabinet	90	140
TOTAL MATERIAL COST	$1,017	$1,545

Figure 13-8. Material cost data for a CCDC receiver.

13.4 TECHNOLOGY

13.4.1 Audio/Video Quality

In video subjective tests of CCDC, the system performed differently across segments of test material. For 8 of the 9 stills, CCDC was judged, on average, to be about 0.5 grade lower in quality than the 1125-line studio reference. For 13 of the 14 motion sequences, CCDC was judged to be about 1.3 grades lower in quality than the reference. The remaining still and the remaining motion sequence, both electronically generated, were judged to be better in quality than the reference.[1]

Problems were noted when the system was subjected to noisy source material. Some problems were noted when the system was tested for motion-compensation overload at high rates of motion. No significant problems were reported when the system was subjected to a sudden stop in motion, to scene cuts, or to two encode/decode operations or when the system was tested for video-coder overload.

Certain tests also were carried out for the 16 QAM Alternate Mode. When judged by non-experts, the 16 QAM mode exhibited a greater reduction in quality than the 32 QAM mode for some moving sequences. Expert observers found little difference between 32 QAM and 16 QAM modes.

During system-specific tests, expert observers noted that the audio remained useful, but not unimpaired, beyond the video POU. There was no evidence that the audio system failed before the accompanying video.

[1] See Section 8.3.3.

13.4.1.1 Video Quality

Subjective judgments of image quality by non-experts are summarized in Figure 13-9. Scores are the differences between judgments of the reference and judgments of CCDC for 9 stills and 14 motion sequences. For 8 of the 9 stills, CCDC was judged, on average, to be 0.5 grade (i.e., about 11 points on the 100-point scale) lower in quality than the 1125-line studio reference; for the remaining still (S14), the system was judged to be 1.4 grades higher in quality than the reference (this may reflect the absence of interlacing artifacts in the 787/788 source and in the CCDC rendering of this picture). For 13 of the 14 motion sequences, CCDC was judged, on average, to be 1.3 grades (i.e., about 26 points) lower in quality than commentary, supported by reports from non-expert viewers, attributed differences between CCDC and the reference to quantization noise, which was particularly visible in saturated reds and which appeared as "busy-ness" that pulsed at about 3 Hz, and to noise and raggedness on high-contrast edges. For motion sequences, expert commentary, again supported by reports from non-expert viewers, attributed differences between CCDC and the reference to the same effects observed in stills, and to exaggeration of source noise and increased quantization noise for the most rapid motion. Expert observers felt that the exaggeration of source noise was a serious artifact. Expert observers noted blockiness only in the most rapid motion.

Comparison of objective tests of static and dynamic resolution showed slight losses in